

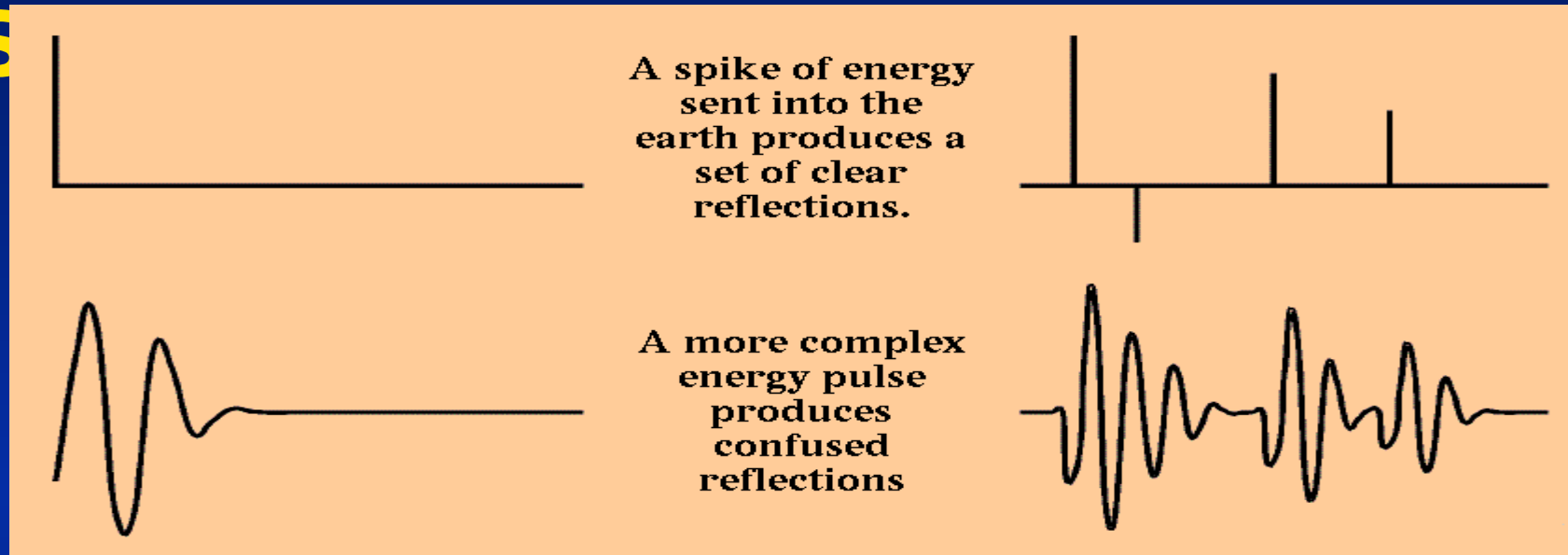
Designature

At the end of this Session, you will be able to:

- **Define the equation for the convolutional model**
- **Define the term deterministic deconvolution.**
- **Describe how a signature can be affected by changes in each of the following : gun depth, cable depth, gun drop outs, air pressure leaks.**
- **Define the term 'zero phase conversion'**
- **Define the term 'minimum phase conversion**
- **Define the term CMS**
- **Produce a schematic diagram that shows the processing steps involved in derivation, application and QC of signature on a shot by shot basis.**

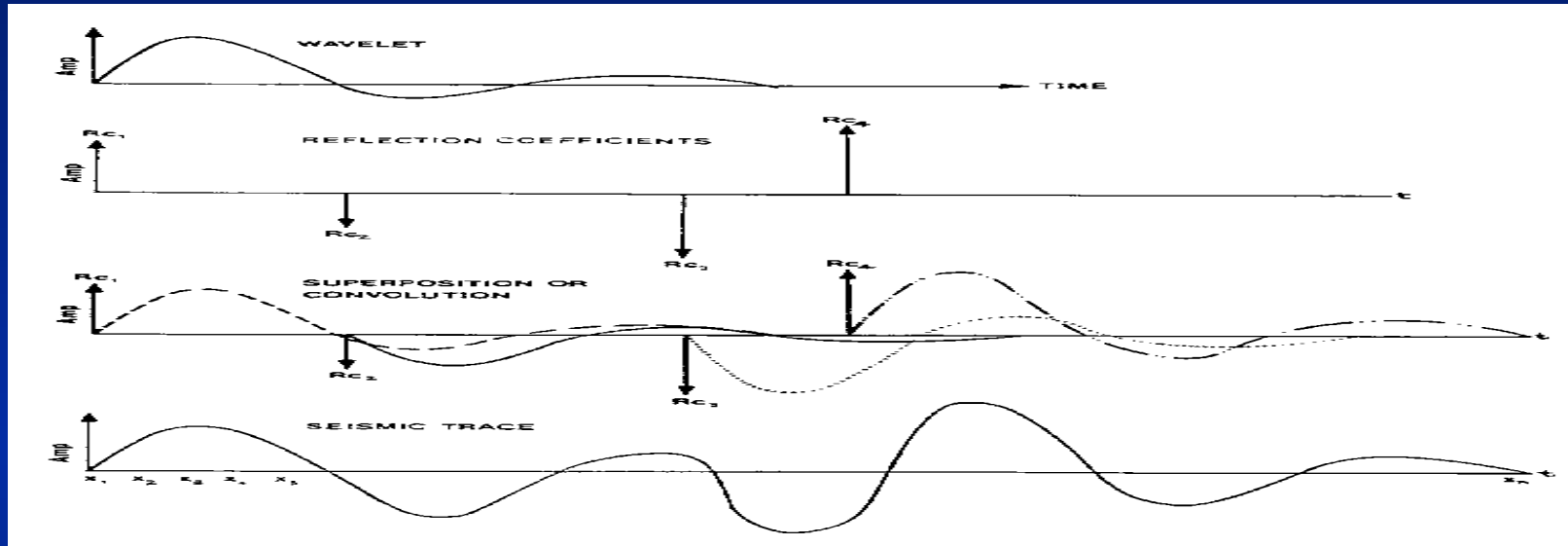
The Role of Seismic

S



- A seismic reflector can only reflect back to the surface an image of the energy pulse it receives.
- If we send a complex pulse into the ground, that pulse will be superimposed on every reflector we record.

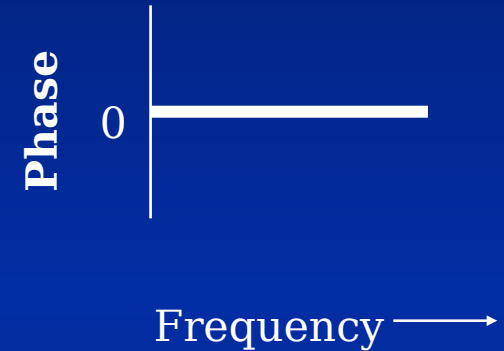
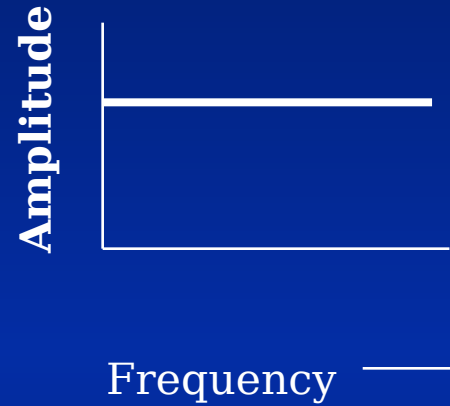
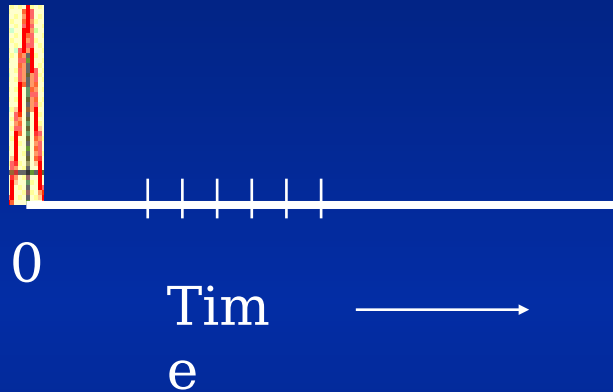
The principle of Superposition



For any linear system (such as earth) and for any input waveform, the output waveform is the superposition of all the impulse-responses obtained by regarding the input waveform as a succession of spikes.

In other words, what we record as a seismic trace, is achieved computationally by convolving the basic wavelet (the signal we send into the earth) with the reflectivity series (layer boundaries) of subsurface earth.

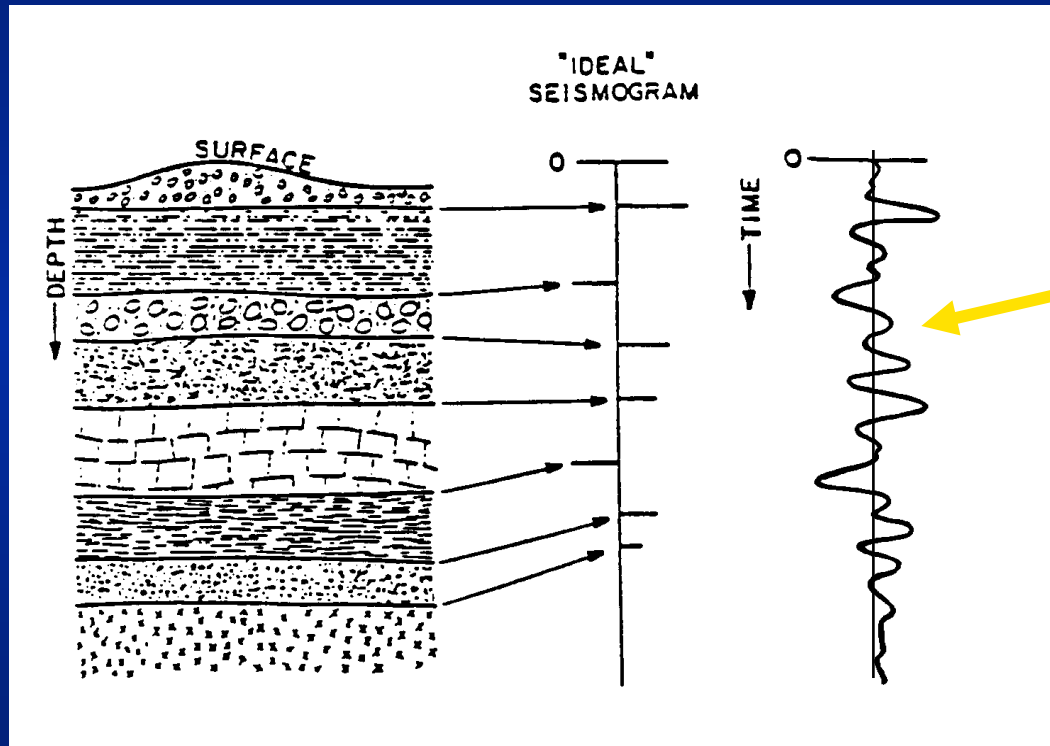
Spectrum of a spike



Acoustic signal generated by an explosive charge is very nearly

Ideal vs Reality

The recorded seismic trace may be modelled as a series of interactions between the source signature (a finite, band-limited wavelet) and the earth.



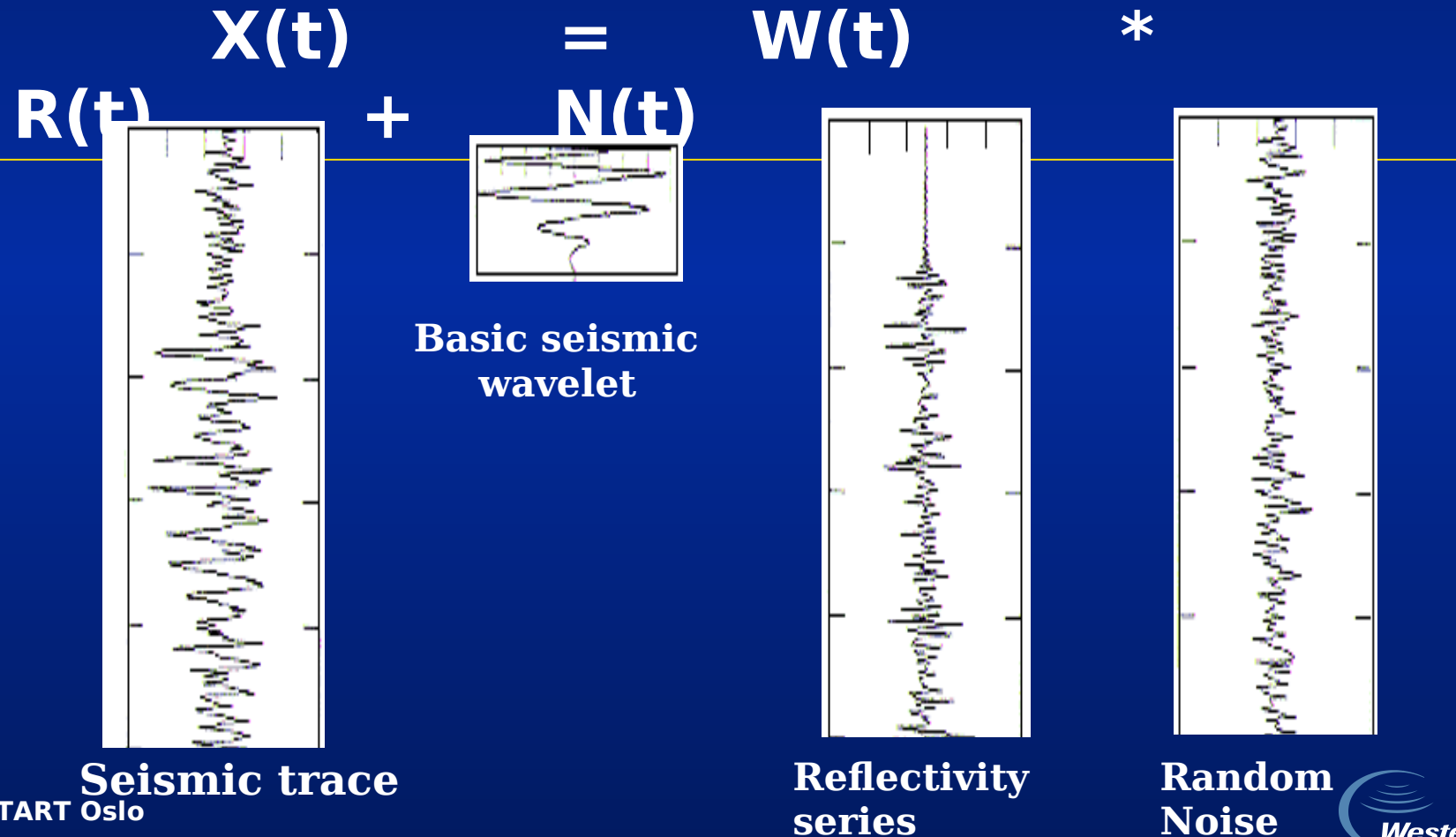
A plot of the reflection coefficients of the layers as a function of two way travel time.

Sedimentary
Column

Reflectivity
Function

The Convolutional Model

A seismic trace $X(t)$ is given by the convolution of the basic seismic wavelet $W(t)$ with the reflectivity series $r(t)$ plus random noise $N(t)$.



Components of the basic seismic wavelet

The wavelet is the combination of all the individual components that affect the seismic wave

For example :

$$\omega(t) = S(t) * S_G(t) * R(t) * R_G(t) * I(t) * E(t) * M(t) * A(t) * P(t) * \dots \text{Etc}$$

But, what are all of these individual components?

Components of the basic seismic wavelet

$$\omega(t) = \mathbf{S(t)} * S_G(t) * R(t) * R_G(t) * I(t) * E(t) * M(t) * A(t) * P(t) * \dots \text{Etc}$$

$S(t)$; Source

$$\omega(t) = S(t) * \mathbf{S_G(t)} * R(t) * R_G(t) * I(t) * E(t) * M(t) * A(t) * P(t) * \dots \text{Etc}$$

$S_G(t)$; Source Ghost

$$\omega(t) = S(t) * S_G(t) * \mathbf{R(t)} * R_G(t) * I(t) * E(t) * M(t) * A(t) * P(t) * \dots \text{Etc}$$

$R(t)$; Receiver

Components of the basic seismic wavelet

$$\omega(t) = S(t) * S_G(t) * R(t) * R_G(t) * I(t) * E(t) * M(t) * A(t) * P(t) * \dots \text{Etc}$$

$R_G(t)$; Receiver Ghost

$$\omega(t) = S(t) * S_G(t) * R(t) * R_G(t) * I(t) * E(t) * M(t) * A(t) * P(t) * \dots \text{Etc}$$

$I(t)$; Recording Instrument

$$\omega(t) = S(t) * S_G(t) * R(t) * R_G(t) * I(t) * E(t) * M(t) * A(t) * P(t) * \dots \text{Etc}$$

$E(t)$; Earth Filter (Q)

Components of the basic seismic wavelet

$$\omega(t) = S(t) * S_G(t) * R(t) * R_G(t) * I(t) * E(t) * M(t) * A(t) * P(t) * \dots \text{Etc}$$

M(t) ; Multiples

$$\omega(t) = S(t) * S_G(t) * R(t) * R_G(t) * I(t) * E(t) * M(t) * A(t) * P(t) * \dots \text{Etc}$$

A(t) ; Array Effects

$$\omega(t) = S(t) * S_G(t) * R(t) * R_G(t) * I(t) * E(t) * M(t) * A(t) * P(t) * \dots \text{Etc}$$

P(t) ; Processing Effects

Deterministic Deconvolution

Deconvolution where part of the seismic system is known. No random elements are involved. For example, where the source wavelet is accurately known we can do source signature deconvolution.

$$\boxed{\begin{matrix} \mathbf{X(t)} \\ + \\ \mathbf{N(t)} \end{matrix}} = \begin{matrix} \mathbf{S(t)} \\ \text{source} \\ \text{signature} \end{matrix} * \begin{matrix} \mathbf{E(t)} \\ \text{system} \\ \text{wavelet} \end{matrix} * \begin{matrix} \mathbf{R(t)} \\ \text{reflectivity} \end{matrix}$$

$\uparrow$
random noise
assumed
to be zero

If we have the recorded source signature then we can do deterministic deconvolution ('de-signature') to remove $S(t)$ from the equation

Source Signature

If we are to remove the effect of our source signature then we must know exactly what our source signature is. Typical practice is for the manufacturers to measure the gun signature and then supply this signature to the acquisition companies. Can you see any problem with this?

Yes

Can source signature be exactly the same every time the gun

No

Can we have air pressure leakage, gun dropouts, cable ghosts, etc.

Gun and Cable Notch Frequencies

Remembering our fourier transform pairs. Depending on the depth of your gun and cable you may see a notch (blip) in your amplitude spectrum. We can calculate the frequency at which this notch will appear using the following equation.

$$750 / \text{Shot Depth Hz}$$

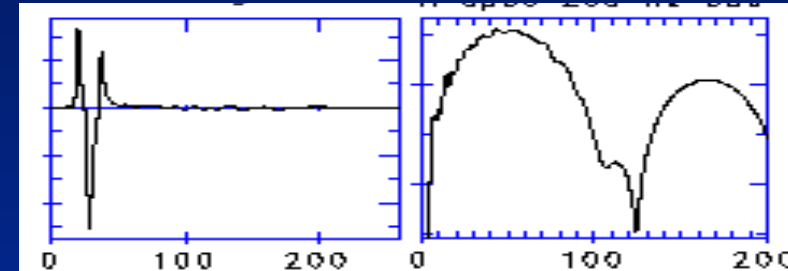
$$\text{Depth Hz}$$

$$750 / \text{Receiver}$$

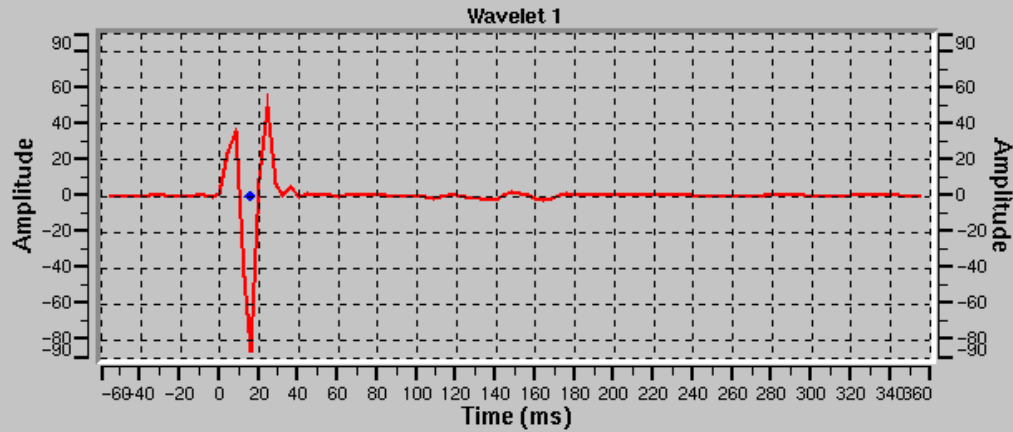
6m depth gives notch at 125Hz
depth gives notch at 150Hz

5m

We try to set the depth of our guns and cables so that their notch frequency will not occur in the frequency range of our seismic data.

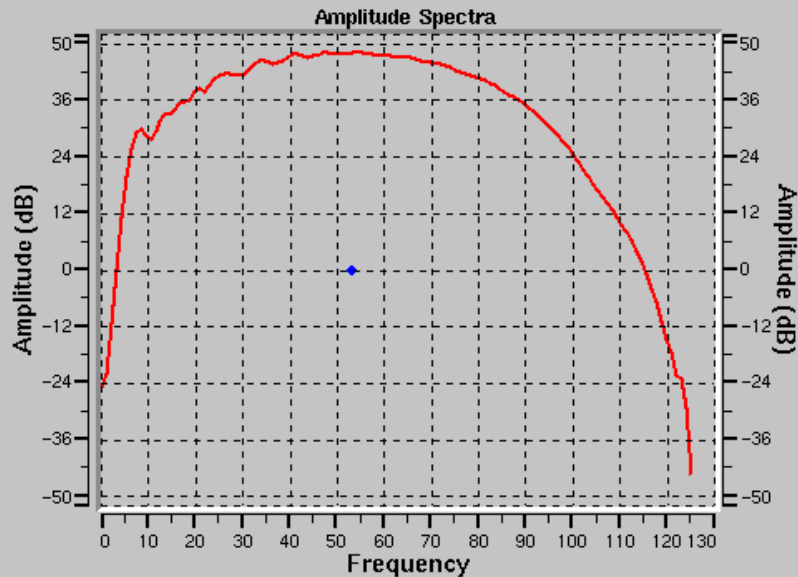


Typical Marine Signature



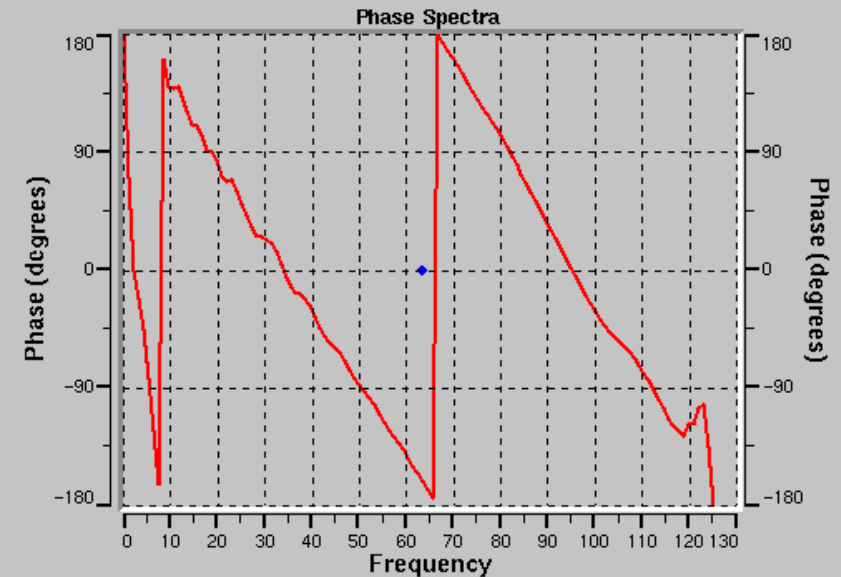
WAVELET <1> OPERATIONS

FILT XFORM SCALE MOD FUNC ATTRIB

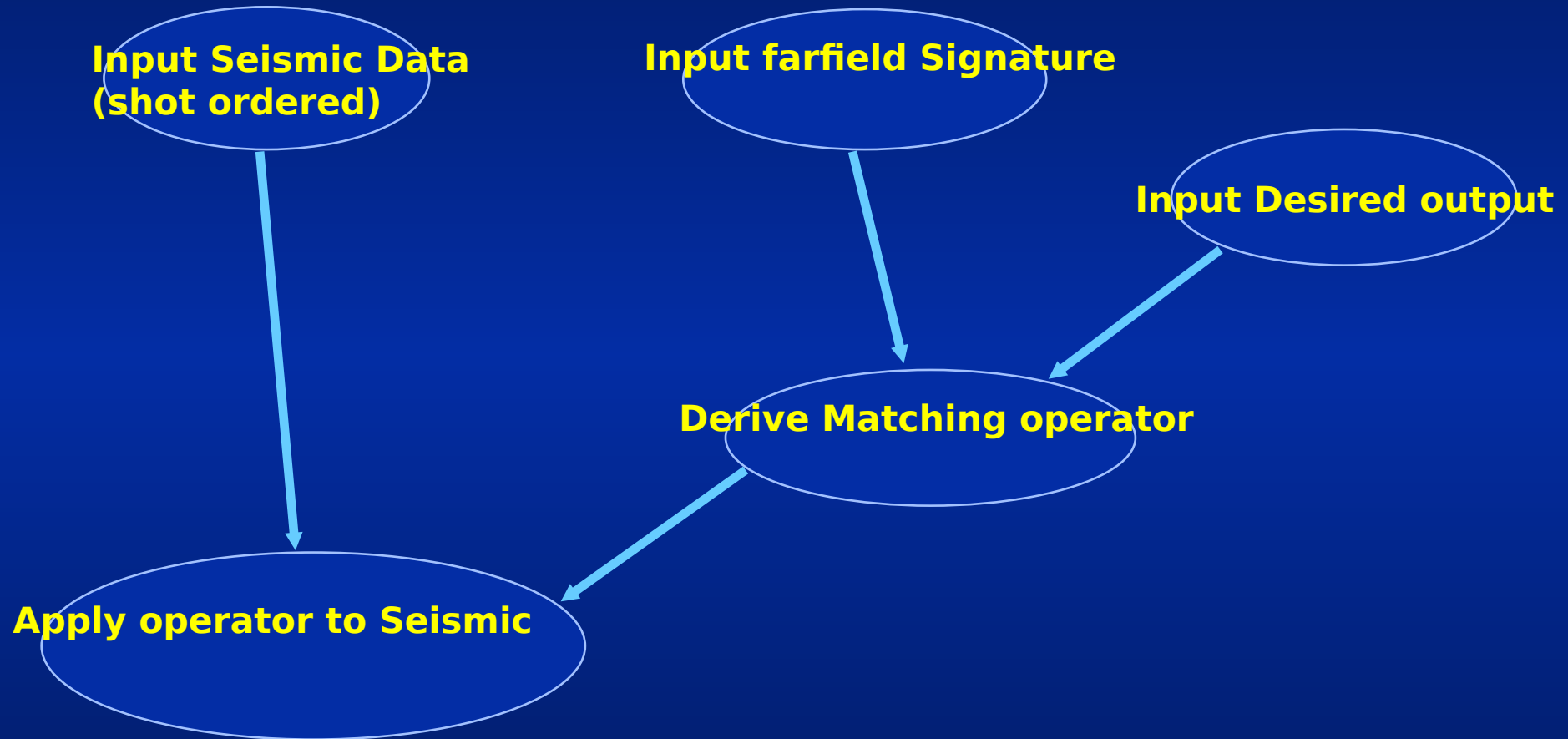


WAVELET <2> OPERATIONS

FILT XFORM SCALE MOD FUNC ATTRIB



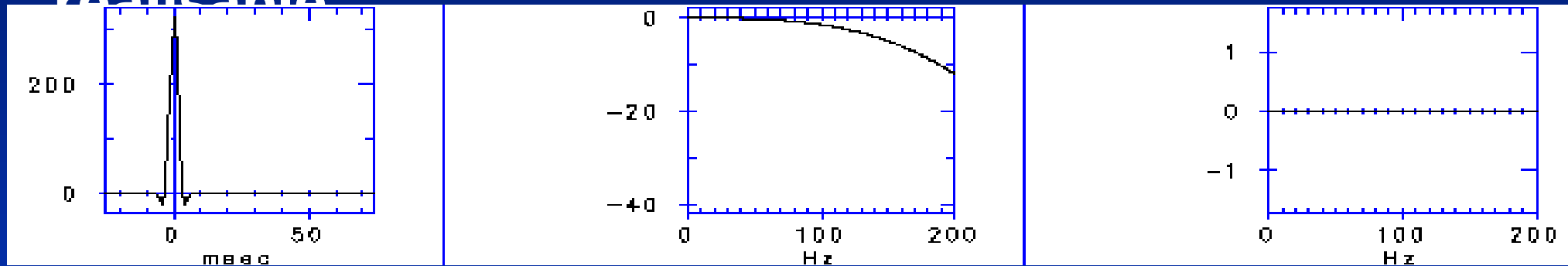
Derivation and Application of Designature Operator



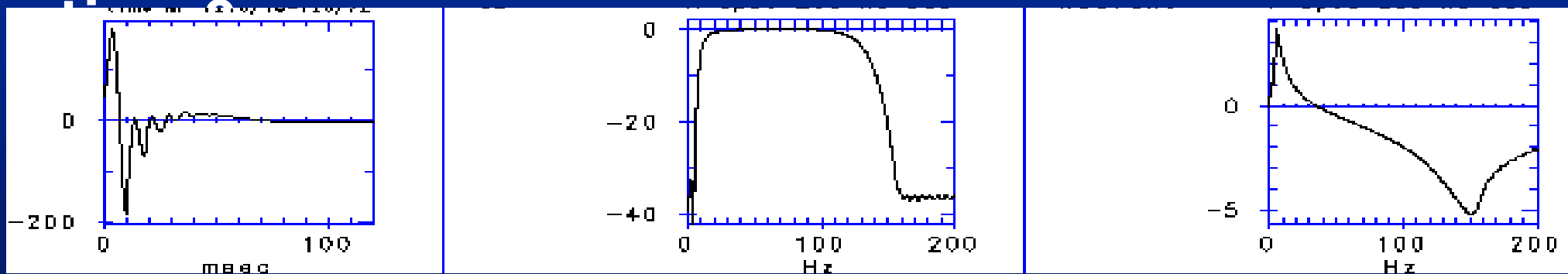
Zero and Minimum Phase

Definitions

A Zero Phase wavelet is symmetric about time 0. It has energy before time 0 and so is not physically realisable.



A Minimum Phase wavelet has its energy concentrated at the front end of the pulse, but has no energy before time 0.

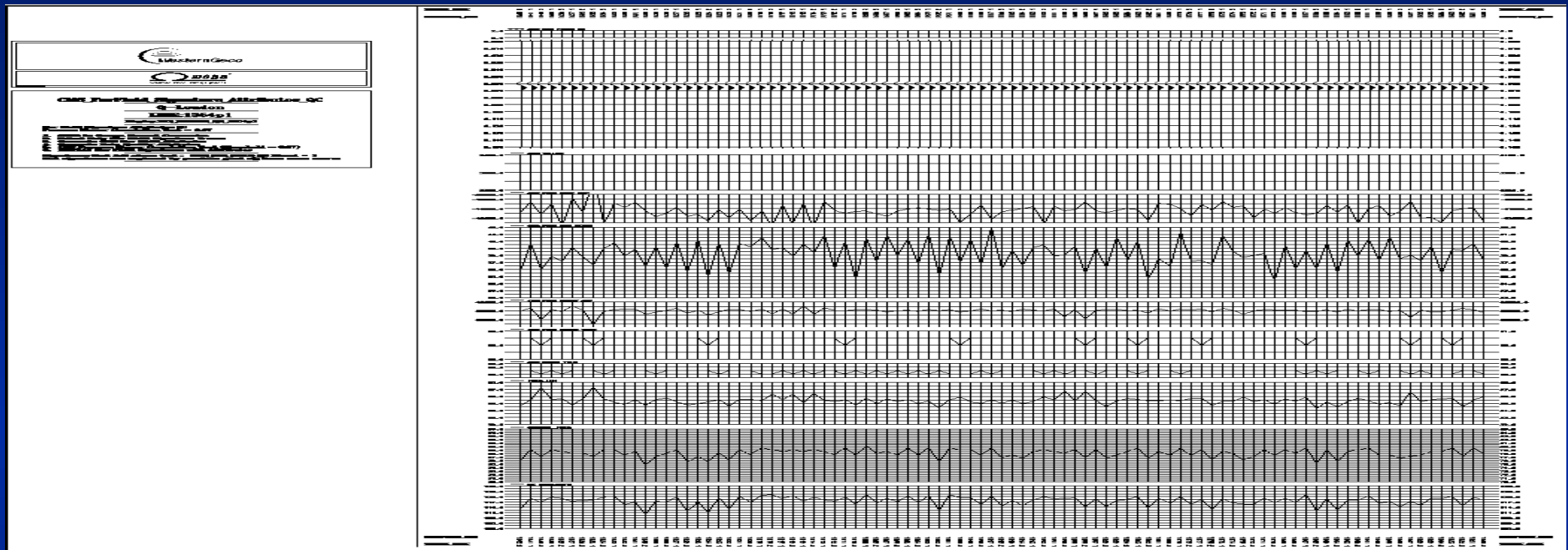


CMS Processing

CMS (Calibrated Marine Source)

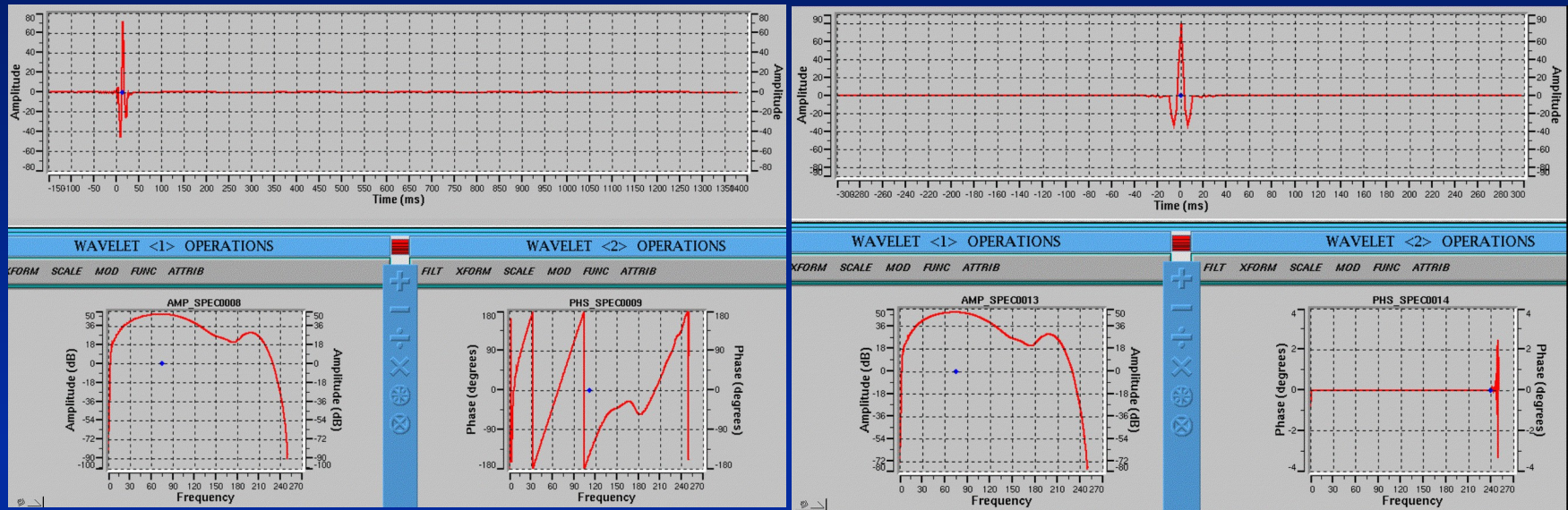
- **CMS allows source-by-source designation to a chosen output wavelet. For each airgun in each array, a near field hydrophone measures the pressure field when the gun goes off. A notional signature is derived for each airgun, it can be thought of as the signature of an individual gun as if it had been fired in isolation, removing the interactions of neighbouring guns. The notional signatures for each airgun in the array are combined to generate the far-field response for each shot. This farfield signature is recorded on an auxiliary trace in the SEG-D record for that shot.**
- **The CMS Processing involves three stages**
 - **QC of Far field Signatures**
 - **Generation of Desired Output**
 - **Generation & Application of source-by-source designation operator**

QC of Far Field Signatures



- Several source attributes are extracted from each far-field signature: array volume, primary peak and ghost amplitudes and times, primary bubble ratio, central frequency.
- These are graphically displayed together with the far-field signatures to allow a visual QC for each sail line
- “Bad” Signatures can be replaced by a neighbour or an average

Generation of Desired Output



Far Field signature after removal of ghosts and debubble

Desired Zero-phase output

- Using the Omega Application SWP (Seismic Wavelet Processor)
- SWP can be used to remove cables ghosts and bubble effects, it can also be used to create a minimum or zero phase output as desired
- Finally it generates the actual designature operator which is applied to each shot to give the desired output

Derivation and Application of Operator for CMS

